AD-A043 958 MICHIGAN UNIV ANN ARBOR COOLEY ELECTRONICS LAB F/G 17/1
BASIC RESEARCH IN UNDERWATER ACOUSTIC PROPAGATION STABILITIES A--ETC(U)
AUG 77 T G BIRDSALL N00014-75-C-0174
UNCLASSIFIED 013514-F NL

1 OF 1
ADA043958

END
DATE
FILMED
9-77
DDC

(5)

Report 013514-F

BASIC RESEARCH IN UNDERWATER ACOUSTIC PROPAGATION STABILITIES AND RELATED SIGNAL PROCESSING

T. G. Birdsall

COOLEY ELECTRONICS LABORATORY
Department of Electrical and Computer Engineering
The University of Michigan
Ann Arbor, Michigan 48109

August 1977

Final Report for Period 1 January 1975 - 28 February 1977

Approved for public release; distribution unlimited.

Prepared for
OFFICE OF NAVAL RESEARCH
Department of the Navy
Arlington, Virginia 22217

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

14

1. REPORT NUMBER: 013514-F

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER: Rept.

6

4. TITLE (and Subtitle): BASIC RESEARCH IN UNDERWATER ACOUSTIC PROPAGATION STABILITIES AND RELATED SIGNAL PROCESSING.

9

5. TYPE OF REPORT & PERIOD COVERED: Final 1 January 1975 to 28 February 1977

6. PERFORMING ORG. REPORT NUMBER: 013514-F

10

7. AUTHOR(s): T. G. Birdsall

15

8. CONTRACT OR GRANT NUMBER(s): N00014-75-C-0174

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Cooley Electronics Laboratory
University of Michigan
Ann Arbor, Michigan 48109

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research
Department of the Navy
Arlington, Virginia 22217

11

12. REPORT DATE: August 1977

13. NUMBER OF PAGES: 18

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 12p.

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Complex channels
Signal processing
Underwater acoustic propagation
Fourier transform
Complex information display
Theory of signal detectability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the theoretical and laboratory work performed under contract N00014-75-C-0174 with the U.S. Navy, Office of Naval Research, during the period 1 January 1975 to 28 February 1977.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

097400

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

1/B

TABLE OF CONTENTS

1. LARGE COMPLEX DATA SETS

A major problem in underwater acoustic research is the search for better understanding of the effects of large scale oceanographic processes that either enhance or destroy coherence. The search for these effects requires the digestion of large complex data sets. The major efforts under this contract were in two areas of research aimed at enhancing our ability to extract information from such data.

1.1 Complex Information Display Using Color

This long term task was aimed at determining the spectral phase stability of noise and man-made signals. The color display facility is a 256 x 256 color point display under computer control. Although quite general in nature, its only use has been to study the spectrum as defined by 256 adjacent bins of an FFT analysis, displaying each analysis below the previous. The spectral magnitude is the displayed brightness, and the spectral phase is the color.

The hardware (electronics and mechanical) had been a major problem since the facilities conception, and it was not until early 1976 that the facility was deemed reliable, and the display free of artifacts. (For example, memory-timing problems caused vertical black lines.)

A modest operating system was written, tested, and completed for control of the display. An effective phase-to-color coding was developed by trial and refinement; this code contains no "white" as only one or two primary colors are excited for each display point. This code appears to be as effective in conveying phase and amplitude information as I had hoped it would be.

The data used for development were taken in January of 1974 in the MIMI Atlantic test. The most obvious conclusion was the need for time overlap (each FFT containing 25 percent new data and 75 percent old data). This agreed with the black and white "gram" display conclusion. Several of the test records showed remarkable signal phase stability; however, it was by chance that the signals' frequency coincided (nearly) with the center of an FFT bin, or this would not have been observed. Signal processing programs to correct this, allowing operator directed cueing and controlled fine-grain-tuning, were written at the close of the contract. This work is expected to continue under other ONR contracts.

1.2 A Data Processing Language

Work was begun under Dr. Gerald Cederquist on a general data processing language that would allow easier manipulation of large data bases, such as the January 1974 MIMI test, with greater assurance of accuracy. This development was discontinued when Dr. Cederquist neared

the end of his post-doctoral stay. Unhappily, the concepts that were beginning to gel were not sufficiently well formulated to warrant reporting; we are, however, a bit smarter than we were. We understand how the use of more complete descriptors aid in analysis of data, and some of the complexities that must be overcome in descriptor transformations as data are processed.

2. SIGNAL PROCESSING

Extension of the theoretical basis for signal processing, and conversion of theory to practice have been low level, but continuing efforts, throughout this contract. Two such efforts warrant reporting here.

2.1 Factor Inverse Filtering

Under this contract and another ONR contract the basis for our previous success using pseudorandom linear maximal binary codes for propagation has been examined, and the techniques generalized. This has been a process that evolved over many years, and we developed and used the techniques before we understood them. Early in 1975 I began to crystallize this into "factor inverse filtering" and have tested it in three experiments. There will be both a report on this (under the other ONR contract) and papers, but the theory is essentially this:

Suppose a propagation experiment is to be conducted from one transmitter to one or more receivers, with the objective of measuring the channel transfer function $C(f,r)$ from the transmitter to the rth receiver. In principle we would like to transmit a short pulse, with spectrum $P(f)$, using due care to match to the transducer's transfer function $X(f)$. If we could measure the channel pulse response, $P(f)C(f,r)$, we would be happy, but the transducer cannot deliver sufficient energy in one short pulse to overcome the noise and

forward scattered reverberation. Therefore we use a coded signal with spectrum $S(f)$ instead.

The key fact is that we have always used, and should use, a signal that contains the hypothetical pulse spectrum as a factor, and the actual signal has spectral zeros only where that pulse spectrum would be zero. Formally

$$S(f) = P(f)G(f) \quad , \; G(F) \neq 0 \text{ anywhere}$$

The actual received spectrum at the rth receiver is

$$R(f,r) = \left[P(f)G(f)\; X(f)\; C(f,r) + \sqrt{N(f,r)}\right] \quad A(f,r)$$

where $A(f,r)$ is the effect of the amplifiers and filters for the rth hydrophone, and the square root on the noise power spectrum, $N(f)$, indicates the Fourier transform of the actual noise on the rth receiver during the measurement. If there were no noise, we would simply solve for the desired result, $P(f)C(f,r)$. Do so.

$$\text{Estimated } [P(f)C(f,r)] = R(f,r) \;/\; G(f)X(f)A(f,r)$$

If a laboratory or "close in" test permits, measure the system without the ocean.

$$\text{Test: } T(f,r) = S(f)\; X(f)\; A(f,r)$$

The denominator in the estimation is $P(f)/T(f,r)$, which will have no zeros. If the signal is chosen carefully,

G(f) will be fairly constant in magnitude, and so will this denominator. The phase function of this denominator is most important, as it undoes the "smearing" done by the transducer and the receiving filters. More important, if array work is being done, the phases of the individual hydrophones will be corrected for individual receiver channel differences. It's really simpler to use than it is to prove. The theory accounts for the signal-to-noise ratio gain due to increased transmission time and loss due to not matched-filtering, all in terms of the "flatness" of the factor spectrum, G(f) .

2 Power Spectrum Measurements

We have been wrestling with the theories and practice of power spectrum measurements for many years. Either our theory is inadequate or our practice is archaic, probably both. Under the previous ONR contract Dr. J. O. Gobien developed the theoretically optimum measurement method for wide sense stationary Gaussian processes with "poles-only" rational power spectra using continuous measurements (not sampled), and optimum in the Baysian sense. That work had some drawbacks: it required perfect analog differentiaters, and the stochastic theory claimed the high frequency falloff was "singularly estimatable," i.e., should be immediately obvious.

Under the present contract a doctoral study by Ron Carpinella analyses the practical implications of Gobien's work when applied to high-sampling-rate digital analysis, compared to Berg's "maximum entropy method" which applies to low-sampling-rate digital analysis. Berg's technique may be treated as assuming an auto-regressive process, which is very close in nature to that treated by Gobien.

This has been a difficult study. The mathematical models are elegant, obtuse, and difficult to manipulate; yet they appear to be inadequate for studying measurable features of underwater acoustic noise. The FFT and third-octave band analyses may be good practical techniques, but they have no support in stochastic theory. At the close of this contract Carpinella was beginning to sort the details from the principles. This work will continue unsupported, and any practical results will certainly show up in subsequent work under other ONR contracts.

Appendix A

TECHNICAL REPORTS AND MEMORANDUMS

The following technical report (thesis) and memorandums were produced wholly or in part under Contract N00014-75-C-0174.

1. G. N. Cederquist, The Use of Computer-Generated Pictures to Extract Information from Underwater Acoustic Transfer Function Data, Cooley Electronics Laboratory Technical Report No. 227, The University of Michigan, Ann Arbor, April 1975. ADA010 229.

2. G. N. Cederquist, CONSYS: A Collection of FORTRAN Subroutines to Produce Contour Maps of Data Surfaces Defined on Rectangular Grids, Cooley Electronics Laboratory Technical Memorandum No. 112, July 1976. ADA027 871

3. G. N. Cederquist, PERSYS: A Collection of FORTRAN Subroutines to Produce Perspective Views of Data Surfaces Defined on Rectangular Grids, Cooley Electronics Laboratory Technical Memorandum No. 113, August 1976. ADA030 152

Appendix B

CONFERENCE PAPERS AND SYMPOSIA

The following conference papers and symposium presentations were supported wholly or in part by Contract N00014-75-C-0174.

1. G. N. Cederquist, "The FLECS Preprocessor for FORTRAN," Computing Center, The University of Michigan, Ann Arbor, October 6, 1975.

2. G. N. Cederquist, "Program Microstructuring," Computing Center, The University of Michigan, Ann Arbor, January 15, 1976.

3. G. N. Cederquist, "A Survey of Recent Practical Developments in the Art of Program Construction," Western Michigan University, Kalamazoo, Southwestern Chapter of Association for Computing Machinery, February 18, 1976.

4. G. N. Cederquist, "An Interactive System for Time Series Analysis and Display of Water Quality Data," 5th International CODATA Conference, International Council of Scientific Unions, Denver, Colorado, June 28, 1976.

DISTRIBUTION LIST

Office of Naval Research	(Code 222)	2
	(Code 102-OS)	1
Department of the Navy	(Code 480)	1
Arlington, Virginia 22217		

Director — 6
Naval Research Laboratory
Technical Information Division
Washington, D.C. 20375

Director — 1
Office of Naval Research Branch Office
1030 East Green Street
Pasadena, California 91106

Office of Naval Research — 1
San Francisco Area Office
760 Market Street - Room 447
San Francisco, California 94102

Director — 1
Office of Naval Research Branch Office
495 Summer Street
Boston, Massachusetts 02210

Office of Naval Research — 1
New York Area Office
207 West 24th Street
New York, New York 10011

Director — 1
Office of Naval Research Branch Office
536 South Clark Street
Chicago, Illinois 60605

Commander — 1
Naval Surface Weapons Center
Acoustics Division
White Oak
Silver Spring, Maryland 20910
ATTN: Dr. Zaka Slawsky

Officer in Charge — 1
Annapolis Laboratory
Naval Ship Research and Development Center
Annapolis, Maryland 21402

Commander | 1
Naval Sea Systems Command
Code SEA 037
Washington, D.C. 20362

Commander | 1
Naval Sea Systems Command
Washington, D.C. 20362
ATTN: Mr. Carey D. Smith (Code SEA 06H1)

Commanding Officer | 1
Fleet Numerical Weather Central
Monterey, California 93940

Defense Documentation Center | 5
Cameron Station
Alexandria, Virginia 22314

Chief of Naval Material | 1
Department of the Navy
Washington, D.C. 20360
ATTN: Mr. James Probus (Director of Navy Laboratories)

Commander | 1
Naval Electronic Systems Command
Washington, D.C. 20360
ATTN: CDR A. Miller (NAVELEX 320)

Commander | 2
Naval Ship Research and Development Center
Bethesda, Maryland 20084
ATTN: Mr. Craig Olson
Unclassified Library

Chief of Naval Operations NOP 224 | 1
Department of the Navy
Pentagon, Room 5E589
Washington, D.C. 20350
ATTN: Capt. A. H. Gilmore

Commander
Naval Undersea Center
San Diego, California 92132
ATTN: Dr. Dan Andrews | 1
Mr. Henry Aurand | 1

Chief Scientist | 1
Navy Underwater Sound Reference Division
P.O. Box 8337
Orlando, Florida 32806

Officer in Charge 3
New London Laboratory
Naval Underwater Systems Center
New London, Connecticut 06320
ATTN: Dr. A. Nuttal
Dr. D. M. Viccione

Commander 1
Naval Air Development Center
Warminster, Pennsylvania 18974
ATTN: Unclassified Library

Superintendent 1
Naval Postgraduate School
Monterey, California 93940
ATTN: Unclassified Library

Commanding Officer 1
Naval Coastal Systems Laboratory
Panama City, Florida 32401
ATTN: Unclassified Library

Commanding Officer 1
Naval Underwater Systems Center
Newport, Rhode Island 02840
ATTN: Unclassified Library

Superintendent 1
Naval Academy
Annapolis, Maryland 21402
ATTN: Library

Commanding Officer
Naval Intelligence Support Center
4301 Suitland Road
Washington, D.C. 20390
ATTN: Dr. Johann Martinek 1
Mr. E. Bissett 1

Commander 1
Naval Sea Systems Command
Code SEA 03E
Washington, D.C. 20362
ATTN: Unclassified Library

Dr. Melvin J. Jacobson 1
Rensselaer Polytechnic Institute
Troy, New York 12181

Dr. Charles Stutt 1
General Electric Company
P.O. Box 1088
Schenectady, New York 12301

Dr. Alan Winder 1
MSB Systems, Inc.
110-16 72nd Avenue
Forest Hills, New York 11375

Dr. T. G. Birdsall 1
Cooley Electronics Laboratory
University of Michigan
Ann Arbor, Michigan 48109

Dr. Harry DeFerrari 1
University of Miami
Rosenstiel School of Marine and Atmospheric Sciences
4600 Rickenbacker Causeway
Miami, Florida 33149

Mr. Robert Cunningham 1
Bendix Electronics Center
15825 Roxford Street
Sylmar, California 91342

John Hopkins University 1
Baltimore, Maryland 21218

Dr. M. A. Basin 1
S.D.P., Inc.
15250 Ventura Boulevard, Suite 518
Sherman Oaks,California 91403

Dr. Walter Duing 1
University of Miami
Rosenstiel School of Marine and Atmospheric Sciences
4600 Rickenbacker Causeway
Miami, Florida 33149

Dr. David Middleton 1
127 East 91st Street
New York, New York 10028

Dr. Donald W. Tufts 1
University of Rhode Island
Kingston, Rhode Msland 02881

Dr. Loren W. Nolte 1
Department of Electrical Engineering FT-10
University of Washington
Seattle, Washington 98195

Mr. S. W. Autrey 1
Hughes Aircraft Company
P.O. Box 3310
Fullerton, California 92634

Dr. Thomas W. Ellis 1
Texas Instruments, Inc.
13500 North Central Expressway
Dallas, Texas 75231

Applied Physics Laboratory 1
University of Washington
1013 Northeast Fortieth Street
Seattle, Washington 98195

Institute for Acoustical Research 2
Miami Division of the Palisades Geophysical
Institute
615 S. W. 2nd Avenue
Miami, Florida 33130
ATTN: Mr. M. Kronengold
Dr. J. Clark
Dr. W. Jobst
Dr. S. Adams

Mr. Carl Hartdegen 1
Palisades Geophysical Institute
Sofar Station
FPO New York 09560

Mr. Charles Loda
Institute for defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202

Mr. Beaumont Buck 1
Polar Research Laboratory
123 Santa Barbara Avenue
Santa Barbara, California 93101

Dr. M. Weinstein 1
Underwater Systems, Inc.
8121 Georgia Avenue
Silver Spring, Maryland 20910

Dr. Thomas G. Kincaid 1
General Electric Company
P.O. Box 1088
Schenectady, New York 12301

Applied Research Laboratories 4
The University of Texas at Austin
P.O. Box 4029
Austin, Texas 78712
ATTN: Dr. Lloyd Hampton
Dr. Charles Wood
Dr. T. D. Plemons

Woods Hole Oceanographic Institute 1
Woods Hole, Massachusetts 02543
ATTN: Dr. Paul McElroy
Dr. R. Porter
Dr. R. Spindel

Mr. John Bouyoucos 1
Hydroacoustics, Inc.
321 Northland Avenue
P.O. Box 3818
Rochester, New York 14610

Systems Control, Inc. 1
260 Sheridan Avenue
Palo Alto, California 94306
ATTN: Mr. Robert Baron

Atlantic Oceanographic and Meteorological
Laboratories 1
15 Rickenbacker Causeway
Miami, Florida 33149
ATTN: Dr. John Proni

University of Miami 1
Rosenstiel School of Marine and
Atmospheric Sciences
4600 Rickenbacker Causeway
Miami, Florida 33149

Westinghouse Electric Corporation 1
Advanced Development Programs
Marketing Department - MS 227
P.O. Box 746
Baltimore, Maryland 21203
ATTN: F. J. Frissyn

Oak Ridge National Laboratory | 1
Union Carbide Corporation
Nuclear Division
P.O. Box X
Oak Ridge, Tennessee 37830

Dr. C. V. Kimball | 1
University of Miami
Rosenstiel School of Marine and
  Atmospheric Sciences
Miami, Florida 33149

Cooley Electronics Laboratory | 25
University of Michigan
Ann Arbor, Michigan 48109